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BUREAU OF ENTOMOLOGY,

L. O. HOWARD, Entomologist and Chief of Bureau.

THE COLORADO POTATO BEETLE.

(*Leptinotarsa decemlineata* Say.[a])

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There are few more familiar insects to the farmer and others who lead a rural life than is the Colorado potato beetle, or "potato bug," as it is commonly known; and yet scarcely more than forty years ago the potato crop of the United States had no very important insect enemy. Not many years later this insect had, by its depredations on potato, one of our most valuable food staples, caused as great concern as have the San Jose scale and cotton boll weevil in the past decade, and was also the subject of much study and experiment. Although so common an insect, many are not thoroughly acquainted with its life history and habits and with the best methods of combating it, and this applies particularly to persons farming in districts only recently invaded by the foe. The insect is continually extending its range southward, and many complaints are received from localities where the pest has not become thoroughly acclimated.

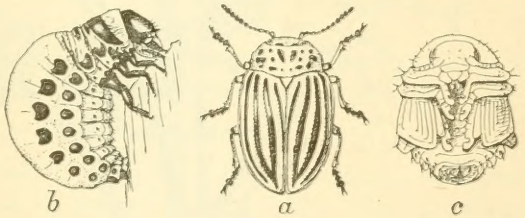

FIG. 1.—Colorado potato beetle (*Leptinotarsa decemlineata*): *a*, Beetle; *b*, larva; *c*, pupa. Enlarged (original).

The potato beetle, notwithstanding all that has been done to suppress it, is still a pest of great importance. It is interesting as the first known example of an insect native to our Western States being introduced eastward and thence practically all over our country and Canada (except on the Pacific coast) where potatoes are grown. In its early days as a migrant there seemed to have been no check to its eastward spread other than natural barriers, such as rivers and lakes and the Atlantic Ocean, but in the course of years numbers of natural enemies—birds, mammals, and predatory and parasitic insects—

[a] Formerly classified and better known as *Doryphora 10-lineata* Say.

have learned to attack it, and, in the case of the insects, they have multiplied until now they are recognized as important factors in the control of the beetle. The species is interesting also as having led to the first use of an arsenical insecticide, Paris green, on edible plants. Fortunately, with a knowledge of the habits of this insect,

FIG. 2.—Section of potato plant showing Colorado potato beetle at work: *a*, Beetle; *b,b*, egg masses; *c,c*, half-grown larvæ; *d,d*, mature larvæ. Somewhat enlarged (original).

the use of arsenicals, and the friendly assistance of natural enemies, the grower may hold it in practical subjection.

DESCRIPTIVE.

The Colorado potato beetle is so well known that a description seems hardly necessary for most persons, but that there may be no

danger of confusing it with any related species or with beneficial ladybirds, a few words of description may be given.

The beetle (fig. 1, *a;* fig. 2, *a*) is of robust form, about three-eighths of an inch in length or a little more, and two-thirds as wide as long. It is ochreous yellow in color, and the wing-covers are ornamented with ten longitudinal black lines. The head is marked with a triangular black spot, and the thorax is dotted with ten or more irregular spots and other markings. The lower surface is also more or less marked with black, particularly the tarsi and knees.

The larvæ (fig. 1, *b;* fig. 2, *c,c, d,d*) are quite as well known as the beetles and are very commonly called "slugs." They are dark Venetian red when first hatched, and as they approach maturity become paler. They are slimy, disgusting looking creatures, soft in texture, and from their peculiar coloration and appearance would not be readily handled by anyone without gloves.

The pupa is red like the larva and looks as shown at *c*, figure 1.

The eggs (fig. 2, *b,b*) are orange colored and are deposited in masses.

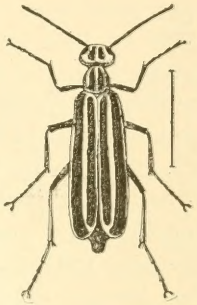

FIG. 3.—Striped blister beetle (*Epicauta vittata*), an "old-fashioned potato bug." (Author's illustration.)

As this beetle is sometimes confused with one or another of the "old-fashioned potato bugs" (blister beetles), a species of the latter is illustrated here for comparison (fig. 3).

ORIGIN AND DISTRIBUTION.

It has always been believed—and, the writer maintains, with reason, until the contrary can be proved beyond doubt—that the Colorado potato beetle, having become dispersed from Colorado as a starting point, originated as a species in that region. Dr. W. L. Tower, however, in a publication issued in 1906,[a] has assumed that this insect had the same origin as its principal wild food plant, *Solanum rostratum*, which he states is essentially tropical, and that the insect has followed the distribution of the plant from Mexico into Texas, New Mexico, and parts of Arizona. He also gives reasons for the belief that *Leptinotarsa decemlineata* has developed from *L.* "*intermedia* Tower" after changing its habitat, the latter occurring in both Mexico and Texas, and the former not being found in Mexico at all, according to his experience.

HISTORY OF THE INSECT'S SPREAD.

The eastward dispersal of this potato beetle from what is generally considered its original home in the West is of peculiar interest. The

[a] An Investigation of Evolution in Chrysomelid Beetles of the Genus Leptinotarsa, Carnegie Institution, Washington, D. C., pp. 23 et seq.

beetle appears to have been first associated with injury to potato in 1865. Forty-five years prior to that time it had been recognized as feeding on the sand bur, or beaked nightshade (*Solanum rostratum* Dunal.), a related solanaceous plant peculiar to the Rocky Mountain region. The beetle was described in 1824 by Thomas Say. With the advance of civilization westward and the cultivation of potato in the vicinity of its native home, the insect acquired the habit of feeding upon this more succulent plant, and about 1859 it had spread to the east as far as Nebraska. Two years afterwards it reached Kansas, and later Iowa, which it traversed in three or four years; so that by 1864 or 1865 it had crossed the Mississippi River and invaded the western borders of Illinois. In its spread through Illinois it was described by Walsh as marching through that State "in many separate columns, just as Sherman marched to the sea; the southern columns of the grand army lagged far behind the northern columns." By 1869 it had found its way to Ohio, appearing almost simultaneously in the northern and western portions. During all this time, beginning with the year 1861, the insect had done considerable injury, and by 1870 it had become exceedingly destructive in the North and Middle West, and was continuing its eastward march at an increasing rate. It had now reached the Province of Ontario. By 1872 its depredations in the West had noticeably abated, owing to the effectiveness of natural enemies and to the increasing use of Paris green. Its progress eastward, however, continued, the northern columns becoming established in Pennsylvania and New York, the southern ones reaching Kentucky. The next year it made its first appearance in the District of Columbia and West Virginia, and in 1874 it had reached the Atlantic seaboard and was reported from Connecticut to Maryland and Virginia.

By the centennial year (1876) the Colorado potato beetle had spread over an area composing more than a third of the United States, so that it occupied at that time more or less completely the States of Colorado, Nebraska, Kansas, Minnesota, Iowa, Missouri, Wisconsin, Illinois, Michigan, Indiana, Ohio, Kentucky, the New England States, New York, New Jersey, Pennsylvania, Delaware, Maryland, Virginia, and West Virginia, and the District of Columbia, in none of which was it native except in the State first mentioned. At that time it occupied also portions of Wyoming and southern Dakota—where it was perhaps also native—and a considerable part of the more arable portions of eastern Canada.

The farther spread of this insect, particularly southward, is of less interest and has, in many instances at least, been dependent more or less on the increased cultivation of the potato. The following additional statements as to the insect's progress are taken from data

collated mainly from the records of this office, some of which are published more in detail by Tower.[a] In 1877 the beetle appeared in North Carolina and Tennessee. The following year it was reported to be completely overrunning portions of Canada, being found eastward in New Brunswick. In 1879 it was recorded from Manitoba. In 1880 its presence was observed in Texas. Since about 1882 complaints of injuries have been made in Nova Scotia; in 1885, at Savannah, Ga.; in 1888, at Jackson, Miss.; and in Smith County, Tex. In 1892 the species had become abundant in Alabama, and was noticed also in South Carolina. The following year its occurrence was observed by H. G. Hubbard at Fort Assinniboine, Mont., which is evidently the most northern limit of its original habitat, as it was not found there on potato. In succeeding years other localities were added in some of the States which have been mentioned, but little of positive interest adding to its known distribution has been learned since 1893. It should be stated, however, that the species has been found at Jacksonville, Fla.; in southern Louisiana, and at San Antonio, Tex., but these extreme localities do not indicate permanent location.

PRESENT DISTRIBUTION.

The natural spread of the potato beetle southward increases from time to time, as evidenced by reports that reach this Department yearly. Undoubtedly, however, the extreme northern and southern territories which it invades do not become permanent habitats for the insect, the species dying out, mainly because of extremes of cold in the one case and of heat in the other, to be reintroduced in later years when conditions favor its multiplication and spread from other regions.

It has been calculated that it increased its range from its original home to the Atlantic coast at an average annual rate of about 88 miles. Its spread eastward was accomplished largely by flight, as the writer had occasion to observe when a resident of Cleveland in the early days of its invasion of northern Ohio. Great numbers of beetles were seen on bright days in spring and early summer, with outspread wings, being carried directly eastward by the winds.

It has also been disseminated largely by railroads and by lake vessels, and has thus been able, through the direct agency of man, to cross the more barren plains bordering its native confines and the barriers made by large bodies of water. So it will be seen that the winds and waters and eastbound trains have all aided in its dissemination eastward. Riley, from whose works the present account of the early distribution of the insect has been taken, observed the

[a] L. c., pp. 36–39.

beetles on Lake Erie in 1870 on various floating objects, and the writer in subsequent years saw the borders of the same lake lined for a foot and more with the hordes of these beetles that had been blown into the water and had then been cast up on the shore.

Beginning with about 1880, it will be noticed, the Colorado beetle appeared in many potato fields of the Gulf region and elsewhere in the South. In certain localities, particularly in Alabama (where it was quite injurious for a time) and South Carolina, this insect seems to have disappeared, and little danger of continuous injury need be anticipated there, as invasions of extreme Lower Austral territory have thus far been merely sporadic appearances. Still, whenever atmospheric conditions favor, the species does temporary damage in such places, only to be killed down again for a number of years, after which the beetles reappear, sometimes invading new localities. It thus will be seen that it would be a somewhat difficult task to outline definitely the permanent distribution of this insect. It is nearly limited, however, as regards severe injuries to the country east of the Rocky Mountains, extending from the Lower Austral to the Transition life zone, and is likely any year to be injurious in extreme portions of this area.

Injuries by this species in the potato section of Aroostook County in northern Maine are well known, and the region there, as well as are portions of Colorado, is credited to the Boreal life zone.[a] From recent reports it is fair to say that the species is scarcely a pest at the present day in its original habitat nor in neighboring States, since during the last five years no reports of extensive injuries have been received from Colorado, Kansas,[b] Nebraska, or South Dakota. It appears to be firmly established, however, in the States just west of the Mississippi River and from there eastward to Nova Scotia and New Brunswick and southward to the northern portions of the Gulf States.

DISTRIBUTION LIMITED BY EXTREMES OF TEMPERATURE.

Some of the conditions which prevent the too rapid multiplication and permanent establishment of the potato beetle are known. At St. Louis, Mo., is was noticed by Riley that during very hot, dry weather, as in 1868, this insect failed to go through its transformations in the ground, the latter becoming so hot and baked that the pupæ dried out, and the beetle, if it succeeded in throwing off the pupal skin, failed to make its way to the surface. It was also noticed that the larvæ frequently perished under the broiling sun when the ther-

[a] These regions may in time be recognized as lying within the Transition zone.

[b] Report from Mr. Warren Knaus, dated May 18, 1907, states that this insect has appeared in great numbers in Kansas and threatens serious damage to young crops.

mometer ranged near 100° F. During the intense heat that prevailed during the summer of 1896 the writer noticed the same conditions in and near the District of Columbia, the eggs and larvæ being literally dried up on the potato plants, and the species temporarily disappearing altogether.

Northward the Colorado potato beetle is practically limited to the Transition zone, although it occasionally invades the Boreal zone, as, for example, in Colorado, where it has been found 8,000 or more feet above sea level. Severe winter weather alone probably has little effect upon the insect, since it hibernates, as a rule, exclusively in the beetle state and deep in the ground. It is, moreover, one of our most hardy species, ranking with the hard-shelled snout-beetles in its resistance to cold and frost. Cold snaps, however, overtake the insect before it has sought out proper hibernating quarters, and when these occur it is doubtless killed off in great numbers. As was predicted years ago, the Rocky Mountains have proved an impassable barrier for this species, and the insect has not been able to reach the Pacific coast or neighboring States west of such barrier.

INJURIES, LIFE HISTORY, AND HABITS.

NATURE OF INJURY.

A few remarks in regard to the nature of the injury inflicted by this insect are pertinent. Beetles and larvæ are destructive in nearly equal proportions. In times of its early occurrence east of its original limit this insect not only caused the entire loss of crops, but sometimes destroyed the potato yield of whole counties and of large portions of some States. Indeed, at one time it materially affected the market price of potatoes, not alone by reason of its direct depredations, but in discouraging farmers from the cultivation of the potato on an extensive scale. Thus in 1873 the price per bushel at wholesale in the St. Louis market reached the high figure of $2. At the present time, fortunately, every progressive grower recognizes the fact that the control of this species is a part of the necessary routine connected with the culture of this tuber.

It was early recognized that the depredations of this insect materially affected the quality of the tuber through the defoliation to which the vines were subjected, and it was at one time difficult to obtain potatoes that were not watery when cooked. This raises the question whether the very marked decrease in quality of potatoes in general at the present day is not due directly to the many years in which the tubers have been deprived of due nourishment by more or less defoliation of the plant itself; for, despite all the remedial measures that are usually practiced, such as the liberal use of arsenicals and "bugging" or jarring, a certain amount of injury nearly

always takes place, which can not fail to affect the tubers when it has occurred practically without intermittence for periods of from twenty to forty years.

FOOD PLANTS.

A wild species of Solanum (*rostratum*, and perhaps also *cornutum*) is an original food plant of this potato beetle, and the latter is probably incapable of developing for any number of generations on plants other than those of the potato or nightshade family (Solanaceæ). The genus Solanum is preferred, and the potato, because of its greater succulence and less acrid taste, is now chosen in preference to plants that grow wild. Still, the insect is nearly always found where its wild food plants grow, particularly where poisons or repellents are used in near-by gardens. It feeds on practically all solanaceous plants, including eggplant, tomato, tobacco, ground cherry (Physalis), thorn apple, and Jamestown weed (Datura), henbane (Hyoscyamus), belladonna, petunia, and pepper. The last is not often attacked, nor are the other plants of different genera from the potato, under ordinary circumstances. Occasionally, when none of these are to be had, the insect will feed on certain weeds and garden plants, among which are cabbage, thistle, and mullein.

It was long ago ascertained that the tender-leaved varieties of potato are most affected, while other kinds, with less tender foliage, such as Peach Blow and Early Rose, are comparatively immune, more particularly when growing in the same field with the preferred variety. Even eggplant seems to be preferred to certain varieties of potato, and is consequently damaged at times, and tomatoes are subject to injury when the foliage of potato is not available.

GENERATIONS.

The normal number of generations of the Colorado potato beetle is evidently two. In fact Tower[a] has observed that this number in both temperate and tropical latitudes is a remarkably constant generic character. In the course of his investigations he has not been able to get the present species to breed more than twice in a season without a period of hibernation or æstivation. Personally the writer has never observed more than two generations in the District of Columbia. Years ago, however, Riley made the positive statement that this species is three-brooded in Missouri,[b] and Lugger has made the same statement in regard to its development in Minnesota. Dr. J. B. Smith claims two generations in New Jersey,

[a] Loc. cit., p. 243.

[b] First Annual Report State Entomologist Missouri, 1869, p. 107.

with sometimes a third partial generation which hibernates in the pupal condition. Considering the fact that this species has invaded new territory and does not live an entirely natural life, having an abundance of food and not being restricted to its single normal plant, it certainly seems possible that a third generation might be produced in an exceptionally warm and humid season, and especially in the most southern localities where it has become established.

LIFE HISTORY.

Hibernation takes place in the beetle stage, under the ground, sometimes to a considerable depth, the beetles having been unearthed from a few inches to several feet beneath the surface. As a rule, however, they do not penetrate deeper than 8 or 10 inches. Exceptionally the beetles winter over in rubbish.

The beetles make their initial appearance quite early in spring, at times issuing from their hibernating quarters soon after the first thaw. At this season they fly readily during the more heated portions of the warmer days, and make aerial journeys of considerable extent. "In flight, the striped elytra are raised and held motionless from the thorax, while the gauzy wings, unfolded and vibrating, strike pleasantly on the eye as the sun intensifies their rosy hues." These flights frequently take place before there are any potato plants for the insect to feed upon, so that as soon as the leaves begin to push their way through the ground the beetles are in readiness for the feast. After a few days of feeding the females deposit their eggs.

The eggs are laid mostly on the under surface of the leaves, and they hatch in from four days to a week or a little later, according to temperature. In from sixteen days to three weeks the larvæ usually attain maturity. They pass through four stages or instars,[a] then descend into the earth and undergo transformation to pupæ and subsequently to beetles, in cells which the larvæ form for the purpose. The minimum period of the pupal stage observed at Washington, D. C., in August, 1906, in a very high temperature with corresponding humidity, was seven days. This will be two weeks to a little longer in a lower temperature. The insect is to be found in practically all stages, and particularly as beetles, during the summer months or as long as any solanaceous plants are available as food. It has been learned that the eggs continue developing in the ovaries during a period of about thirty-five or forty days, and it is probable that this species, in common with some others, has the ability of retaining the eggs until a suitable place has been offered for their

[a] Observed by Messrs. A. A. Girault and A. H. Rosenfeld at Myrtle, Ga., in May and June, 1906.

deposition. A single female is said to be capable of producing from five hundred to a thousand eggs. Five hundred and twenty-five were observed by Girault and Rosenfeld in the case of one female, laid in masses of from 9 to 53, from May 21 to June 5.

The entire life cycle from egg to adult may be passed in about four weeks. The beetles of the last generation issue early in autumn, feed for another three or four weeks, and then enter the earth for hibernation.

NATURAL ENEMIES.

It has already been stated that atmospheric conditions, with the exception of extreme heat in its more southerly range, are not especially important factors in the repression of this species; hence its fluctuation in numbers, which is noticeable at least locally every season, must be accounted for by the activity of its insect enemies, the numbers of which are legion. Several groups of these enemies are known, each of which contains, as a rule, many species. Among the most important are ladybirds,[a] many common species of which, in both their larval and adult stages, prey upon the potato beetle, destroying great numbers of its eggs and young larvæ. One of the commonest of these ladybirds is illustrated for comparison with the Colorado beetle by figure 4.

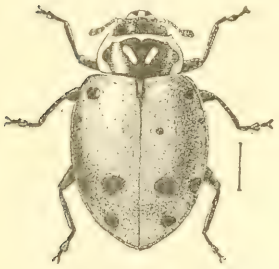

FIG. 4.—A ladybird (*Hippodamia convergens*) which preys on the Colorado potato beetle. Enlarged (author's illustration).

FIG. 5.—*Lebia grandis*, an important potato-beetle enemy. Enlarged (Marx, del.).

Several ground-beetles,[b] also of predaceous habits, attack and devour the larvæ of this potato beetle, and of these the so-called great Lebia (*Lebia grandis* Hentz, fig. 5) is particularly attached to this species, following it wherever it goes and doing perhaps more effective service than any single natural enemy of which we have knowledge. Several soldier-bugs also attack it, one of which, the spined soldier-

[a] The ladybird enemies of this species are: *Coccinella 9-notata* Hbst., *C. sanguinea* L., *Megilla maculata* DeG., *Hippodamia convergens* Guér., *H. 13-punctata* L., *H. glacialis* Fab., *Anatis 15-punctata* Ol. (*ocellata*), and *Chilocorus bivulnerus* Muls.

[b] Carabid enemies include the great Lebia (*Lebia grandis* Hentz), the fiery ground beetle (*Calosoma calidum* Fab.), *Pasimachus elongatus* Lec., *Harpalus caliginosus* Fab., *Lebia atriventris* Say, and *Brachynus kansanus* Lec.

bug,[a] is illustrated at figure 6. Other natural enemies are robber flies,[b] spiders, and a tachina fly.[c] This last develops within the body of the potato beetle larva and has been observed so abundant in potato fields that its buzzing resembled the noise made by the swarming of bees. Wasps of some species attack the larvæ, and the rust-red social wasp[d] has been seen carrying them to provision its nest. Not infrequently the beetle is found partly covered by dull, yellowish, rounded mites. These are external parasites[e] and help somewhat in reducing their hosts. A species of daddy-long-legs is also a natural enemy.[f]

Other predatory insects include a tiger beetle (*Tetracha virginica* L.) and two rove-beetles (*Philonthus apicalis* Say and *Quedius molochinus* Grav.). Most of the species listed above have been recorded by Riley, but many have also been observed independently by others, and correspondents of this Bureau frequently call attention to the commoner forms.

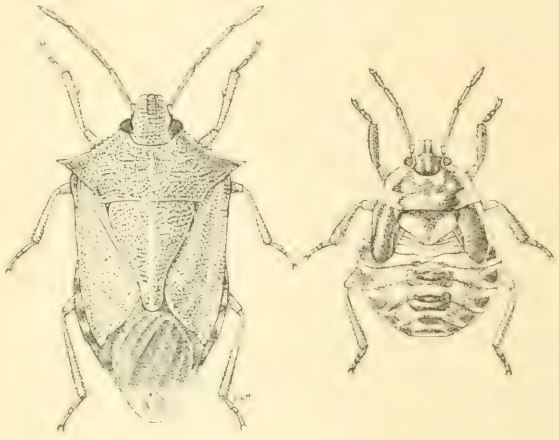

FIG. 6.—The spined soldier-bug (*Podisus maculiventris*): Adult at left, nymph at right. Much enlarged (original).

Thus far only insect foes of the potato beetle have been discussed, but certain mammals, birds, amphibians or batrachians, and reptiles are well-known enemies. One of the most important of the birds is the rose-breasted grosbeak, whose services as an enemy of this beetle have been little appreciated until comparatively recent times. The bobwhite or quail[g]

[a] The soldier-bugs include *Podisus maculiventris* Say [*spinosus*], *P. cynicus* Say, the bordered soldier-bug (*Stirotrus anchorago* Fab., *Perillus circumcinctus* Stål., *P. claudus* Say, *Milyas cinctus* Fab., and *Sinea diadema* Fab. These commonly attack the larval potato beetle. *Nezara hilaris* Say and *Euschistus variolarius* Beauv. are said to have the same habit, but can not be important enemies, as they are naturally herbivorous.

[b] *Proctacanthus milbertii* Macq.

[c] *Phorocera* (*Lydella*) *doryphoræ* Riley.

[d] *Polistes rubiginosus* Lep. *P. pallipes* Lep. is said to have the same habit.

[e] The most abundant of these is *Uropoda americana* Riley.

[f] *Liobunum* (*Phalangium*) *dorsatum* Say.

[g] This bird is one of the most important enemies of an equally destructive species, the chinch bug.

also does excellent service and destroys many. Other birds which are known to eat the potato beetle, on the authority of the Biological Survey, are the following: Ruffed grouse, nighthawk, cuckoo, scarlet tanager, the wood, hermit, and olive-backed thrushes, and robin. The crow not only picks beetles from the vines, but digs them from the earth. The cardinal is a well-known potato-beetle destroyer, and even the English sparrow has been seen to eat them.

Domestic fowls are of some assistance in destroying this pest, and of these the duck early took to this insect, which is distasteful to some other fowls. For some time after the spread of the Colorado beetle to new territory chickens did not attack it, presumably because it has, in common with many other leaf-beetles, a nauseous taste. For several years, indeed, it was believed to be actually poisonous. After a time, however, chickens became better acquainted with this insect and began devouring its eggs and afterwards the larvæ, finally eating the beetles with apparent relish. Skunks and snakes are reported to eat the beetles, and toads frequently gorge on them.

METHODS OF CONTROL.

This species is not a difficult one to control, no other method being necessary for its destruction than the free use of an arsenical or mechanical means. Before taking up the remedies that may be most profitably employed, it may be well to preface with the statement that an arsenical liquid *spray* is preferred, and that dry arsenicals, hand-picking, and jarring are practicable only on a small scale where the grower has no spraying outfit, and occasionally when infestation is slight and limited to a small area. Every market gardener should be equipped with a *good* spraying outfit.

MECHANICAL METHODS.

Jarring, if employed early in the season, is of considerable value. It is a time-worn remedy and so well known as scarcely to need description. It is customary in many localities to gather the beetles and their larvæ in pans containing a little water on which a very thin scum of kerosene is floating. Large shallow milk pans are excellent for this purpose. At the same time the egg masses should be picked where seen. Numerous appliances have been invented and some patented for destroying this pest, but the arsenicals are so effective that other remedies are really not necessary.

Brushing.—The susceptibility of potato-beetle larvæ to extreme heat, as has already been recounted, indicates that a remedy much in vogue against the asparagus beetle, namely, the mere brushing of the larvæ from the plants on an extremely hot and dry day, will be effect-

ive. So far as the writer knows, however, this has never been given a thorough trial for the potato beetle. It should be tested.

Fall and spring plowing are of value in a general way, as for other insects which pass the winter in the earth, but they are by no means perfect measures, as the beetles are hardy and not much affected by this treatment.

ARSENICALS.

Arsenicals are the best remedies for the Colorado potato beetle, and on small potato patches Paris green is usually applied dry, mixed with flour; but, as previously stated, it is best used as a spray. Where early hand methods have been employed, thorough treatment with an arsenical should follow.

Paris green, dry.—When applied dry, Paris green is mixed with from 10 to 20 parts of cheap dry flour, sifted land plaster, or fresh air-slaked lime. This remedy affords best results early in the season on young plants. It should be dusted on preferably when the dew is on and by means of powder guns or bellows, or the so-called "dust-spray" machines, so as to cover the plants and leave as little surface as possible for food for the first-appearing beetles. In spite of this, however, some beetles will succeed in depositing their eggs on the lower surface, which is difficult to reach with a dry mixture, and when the larvæ hatch another application must be made. In fact this remedy must be used for some time or until the plants obtain a fair growth, when spraying will be found more effective.

The Paris green spray is prepared by mixing the arsenical with water or Bordeaux mixture[a] at the rate of 1 pound of poison to 75 to 125 gallons of the diluent. If water alone is used, quicklime in about the same proportion as the poison should be added to prevent scorching. For the proper mixing and application of this spray a bucket pump or knapsack sprayer of good quality is sufficient for use in small gardens, but on a larger scale a potato sprayer to be drawn by one or two horses through the rows of plants is necessary. With the latter, from two to six rows can be treated at a time. Special four and six row potato sprayers are on the market. The Paris green should be mixed with a small quantity of water into a thin paste before the bulk of water is added and should then be thoroughly blended by churning in the force pump or sprayer. The mixture, being a mechanical one, is not constant, and the Paris green will sink to the bottom. To avoid this it must be stirred constantly while being applied. It is advisable to use the Bordeaux mixture as a diluent, as this is a valuable insect repellent as well as a standard

[a] Directions for the preparation of this fungicide and the arsenicals here discussed are given in Farmers' Bulletin 127, U. S. Department of Agriculture, which can be obtained on application to this office.

fungicide, and it operates also against different forms of blight and other diseases which may threaten the crop.

Arsenate of lead serves the same purpose as Paris green, and for use against the Colorado potato beetle is still more valuable. Complaints have been made that several applications of Paris green are necessary during the season, and extra doses are required after each rain. Arsenate of lead is applied in practically the same manner as Paris green, but it contains less poisonous arsenical (60 to 70 per cent when dry), and being sold usually in the form of a paste it is used at a considerably greater strength—i. e., about 1 pound combined with 15 to 25 gallons of water or Bordeaux mixture. Being more adhesive, it adheres more firmly to the leafage and is much less likely to produce scorching.[a] Its adhesiveness is still more enhanced by the addition of about the same amount, by weight, of resin fish-oil soap as of the arsenical used.

The number of sprayings to be applied will depend somewhat upon local and seasonal conditions. Two or three will ordinarily suffice for the spring brood, especially if applied just after the eggs have hatched, and the same number should be applied for the second generation.

Other arsenicals may be used if preferred. Among these are arsenite of lime with soda, which has the merit of being as efficient as Paris green and lime and far cheaper. It is not on sale at the present time ready made, like arsenate of lead. Scheele's green, similar to Paris green, is employed in the same way as the latter.

Summary.—To sum up the directions for the use of arsenicals, it should be said that arsenate of lead, because it can be purchased already combined, in paste form, which is preferable, takes first place, in the writer's opinion, as a potato-beetle insecticide. The mixture of Paris green, lime, and water is in nearly the same class, because the ingredients can be purchased anywhere. The dry Paris green mixed with air-slaked lime properly comes last, as it is less effective than the other mixtures and much of the material is wasted.

Precautions to prevent poisoning.—In the use of arsenicals, as well as other poisons, care should always be taken to avoid accident. This can be best accomplished by plainly marking the contents on all receptacles, such as bottles or packages, in which the poison is kept. In addition a " POISON " label, which can be obtained of any druggist, should be affixed. It is best also to keep such substances under lock and key. The utensils employed in the preparation of the mixtures which have been discussed should be thoroughly cleaned after use.

[a] In point of fact it can be used at the rate of 1 pound to 10 gallons without injury, but this proportion is not advisable, owing to the extra cost, and scorching would be apt to follow its use on plants exposed to hot sunlight.

ERADICATION OF WEEDS AND COOPERATION.

It is always wisdom on the part of the agriculturist to keep down the weeds on the farm, and in the treatment of the present insect if those weeds which are known to furnish it with food, such as sandbur and Jamestown weed, were cut just before seeding, it would prevent the overdevelopment of the pest and of other insects which feed on the weeds, as well as the weeds themselves. The farmer should familiarize himself with the wild food plants of this pest.

Keeping the potato patch and, in fact, the entire farm as free as possible from solanaceous weeds should be practiced by all farmers of a neighborhood, and if the potato grower could secure the cooperation of his neighbors in the use of an arsenical spray, and would also destroy the insects by spraying infested wild food plants, the effect would soon be noticeable, as there can be no doubt that the species would soon be reduced to small numbers, at least in limited areas, if this cooperation were thorough and persistent. This statement is based on the fact that the beetles are seldom if ever seen migrating nowadays in any such numbers as in earlier years, and there is not therefore the constant danger of reinfestation from a distance as was formerly the case. There may, of course, be occasional exceptions.

Finally, as a general proposition, the potato grower should keep his potatoes free from diseases, such as wilt and scab, and spray for flea-beetles and any other insects which may be found in addition to the Colorado beetle. He should also pay particular attention to the methods of growing best adapted for his location. Information in regard to the methods of potato culture is furnished in Farmers' Bulletin No. 35, U. S. Department of Agriculture, and potato diseases and their treatment are considered in Farmers' Bulletin No. 91. Both of these publications can be had on application to the Secretary of Agriculture.

Approved:

JAMES WILSON,

Secretary of Agriculture.

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